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AUTHOR Start, Jay
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ABSTRACT

A number of variables may affect the ability of students to perceive, and learn from, instructional materials. The objectives of the study presented here were to determine the projected color that provided the best visual acuity for the viewer, and the necessary minimum exposure time for achieving maximum visual acuity. Fifty volunteers--undergraduate students at Duquesne University in Pittsburgh--participated in the study. All subjects were given eye examinations for visual acuity and color deficiency (Graham-Field Acuity Test and Ishihara Color Vision Test), and Kodak photography equipment was used to project a series of 208 stimulus slides with black backgrounds which were randomly presented at both pre-set and subject-controlled intervals. Each series of slides varied in the color of the symbols and the symbol gap direction, and three different hues of four colors representing the widest portion of the visible spectrum--red, blue, green, and yellow--were used. The findings indicated that white is the best color to use when designing instructional materials, followed by middle yellow, dark yellow, light yellow, light blue, middle red, light green, dark red, dark blue, middle blue, middle green, and dark green; the longer the amount of time a visual is on a screen the more likely it is to be seen; and, in general, a subject's ability to corrrectly perceive a message, regardless of color, increases as the time of presentation of the message increases. (CGD)

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The Best Colors for Audio-Visual Materials for More Effective Instruction

Author:

Dr. Jay Start

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TITLE: THE BEST COLORS FOR AUDIO-VISUAL MATERIALS FOR MORE EFFECTIVE INSTRUCTION.

AUTHOR: Dr. Jay Start, Indiana University of Pennsylvania

RATIONALE:

The use of instructional materials in education has been given universal acceptance as, not only an aid, but in some instances, a primary force in the educational process. However, when designing materials there are many variables that can have an effect on the intended audiences ability to percieve and in turn learn from the materials. Variables such as time, color, and the interaction of time and color have been shown by previous research to play an important role in the learning process. Metcalf (1968) studied the effect on visual acuity of black and white slides and viewer angle. Costello (1969) studied captions and readability of slides. Snowberg (1972) studied subjects visual acuity of slides with colored backgrounds and white symbols.

Since Metcalf (1968) examined black backgrounds and white symbols, and Costello (1969) sought to determine the most readable captions, and finally Snowberg (1972) studied black symbols on colored backgrounds, the question arises about the effect of black backgrounds and colored symbols. What happens to visual acuity when colored symbols are used? And what role does time play on visual acuity? The present study was undertaken to examine these questions.

The purpose of this study was twofold: 1. Determine what projected color provides the best visual acuity for the viewer. 2. Determine the minimum exposure time necessary for maximum visual acuity.

To answer these questions the following research questions were investigated:

1. When illumination, distance and reflectance remain constant, do various colors differentially facilitate the recognition of Landolt Ring placement?

2. Does an interaction exist between stimulus exposure time and the degree to which various colors facilitate recognition of Landolt Ring placement?

METHODOLOGY

The methodology of this study can be described in five categories: selection of the population, instrumentation, stimulus materials, experimental procedures, and, research design.

1. Selection of the population

The population for this study consisted of 50 undergraduate students, all of whom were be between the ages of 18-22. All subjects were enrolled in the Communication program at Duquesne University, Pittsburgh, Pennsylvania. Participation in this study was on a volunteer basis. Students were urged to participate but also assured that their grade would not suffer or improve because of non-participation or participation.

All subjects were given eye examinations for both visual acuity and color deficiency. Those individuals failing the eye examinations for color deficiency and/or visual acuity were illiminated from the test population.

2. Instrumentation

All testing took place in two rooms. One room was used for testing visual acuity and color visual deficiencies. The other room was used for the presentation of the stimulus. The available light in this room was between 10 and 15 Foot Lumens at all times during testing.

Stimulus materials were projected using a Kodak Ektagraphic Model B-2 Carrousel slide projector with a Kodak f 3.5 projection Ektanar zoom lens. The light source was a General Electric 300 watt quartzline lamp ELH 120 volts with a color temperature of 3,375 degrees Kelvin.

Screen reflectance was measured and was the same for each stimulus slide. This was achieved by using neutral density filters.

The time in which the stimulus slides appeared on the screen was controlled by an Ilex Optical Co., Calumet Caltar no. 5 Universal Synchro f 6.3 variable speed lens. The f-stop during testing remained completely open at f 6.3. Both front and rear lens elements were removed so as not to interfere with stimulus projection. Lens speeds were checked by a certified camera technician using an oscilloscope in order to ensure accurate speeds.

3. Stimulus Materials

The colors red (hues 1, 2, 3), blue (hues 1, 2, 3), green (hues 1, 2, 3), and yellow (hues 1, 2, 3) were chosen because they represent the widest portion of the visible spectrum.

To provide three different hues of each color, gels were sandwiched or stacked one upon another as follows;

Roscoe, Lene 821 = Red (1)
Roscoe, Lene 821 + Lene 821 = Red (2)
Roscoe, Lene 821 + Lene 821 + Lene 821 = Red (3)

The above method was also used for Green, Blue, and Yellow.

It was found when previous research was examined that there are two basic tests used when testing visual acuity, Snellen Letters and Landolt Rings. However, when testing color vision Graham (1965) recommends Landolt Rings. When Landolt Rings are used, the observer is asked the location of the gap. The direction of the gap is changed to provide variability.

To determine the proper symbol size the following formula was used:

$$\tan a/2 = s/2d$$

where;

a = visual size
s = size of the object
d = distance of subject from object in the same measurement terms as the size of the object.

(Metcalf, 1969, p.56)

According to Metcalf (1969), after all calculations are completed, the proper symbol gap size is 2 millimeters at 20 feet. Slides were made from paste-ups of the symbols used. The color gels were sandwiched over the symbols. All slides were made using Kodak 35mm high contrast film. Exposure time and development time was the same for each slide to insure uniformity. Slides were mounted in Kodak 2" X 2" plastic slide mounts along with the the colored gels and neutral density filters.

In order to vary the time at which each slide was presented, a variable speed lens with the front and back lens elements removed, was placed in front of the projector lens. The shutter was then opened and the slide focused on the screen. The opacity of the shutter leaves did not permit any light to leave until the shutter was triggered by the operator.

4. Experimental Procedures

A population identification sign up sheet was distributed to students enrolled in Communication courses at Duquesne University. After which subjects were chosen and contacted by the researcher and given an appointment for testing. At which time subjects were asked to read and sign a Human Subjects Consent form before the test was conducted.

After completing a Graham-Field Visual Acuity Test (a standard opthomological test) and an Ishihara Color Vision Test, subjects were seated 20 feet at a 90 degree angle from the screen. The room was darkened, and the following instructions played to the subjects via cassette tape recorder.

> Please look at the screen while I give you the instructions. You will be presented with 208 slides. They will

> either be yellow, blue, green, red, or white. They will be presented at various speeds; although with some, you will be given as much time as you feel is necessary.
>
> After a slide is presented, you will indicate on your answer sheet what direction the break in the circle is, right, left, up, or down. If you cannot tell the direction of the gap, put an X on your answer sheet. After you have decided, tell the operator to continue.
>
> Please stay seated until you are told by the operator that the test is over. Refrain from leaning forward or squinting.
>
> Before we begin, are there any questions?

After the instructions were presented, subjects were given answer sheets.

Subjects were presented with 208 2" X 2" slides. Each series of slides varied in color and symbol gap direction. The speeds in which the slides were presented were 5 seconds, 10 seconds, 15 seconds, and for as long as each subject felt it was necessary. The order in which the slides were presented was determined using a table of random numbers. From which a stimulus presentation order sheet was prepared. It took approximately 30 minutes to complete the test, depending on the length of time it took the subjects to respond.

5. Research Design

This study was a 4 x 13 repeated-measures design. (4 speeds x 13 colors)

The independent variables for this study are color, and exposure time. The dependent variable was each subject's response to the presentation stimulus.

FINDINGS AND CONCLUSIONS

Analysis of the Data

The results of this study were analyzed by means of an Analysis of Variance for repeated measures and are summarized in Table 1.

As can be seen in Table 1, there were three significant effects obtained from the analysis of the data gathered in this research, providing affirmative answers to the two main

effects hypothesis and as well to their interaction: Color ($F = 136.43$; $df = 12/588$; $p < .001$), Time ($F = 7.28$; $df = 3/147$; $p < .001$), Color x Time ($F = 6.15$; $df = 36/1764$; $p < .001$).

TABLE 1. ANALYSIS OF VARIANCE SUMMARY TABLE

Source	df	ss	ms	f
Color	12	1980.01385	165.0015	136.43 ***
Error	588	711.14000	1.20942	
Time	3	6.95692	2.31897	7.28 ***
Error	147	46.85077	0.31871	
Color x Time	36	75.46308	2.09620	6.15 ***
Error	1764	601.22923	0.34083	

*** p <.001

Main Effects Statistics.

Table 2 presents the rank order of correct visual acuity test means, with time collapsed across all colors.

TABLE 2. RANK ORDER OF CORRECT VISUAL ACUITY TEST MEANS, WITH TIME COLLAPSED ACROSS ALL COLORS.

Color	Level	Mean
White		3.945500
Yellow	(2)	3.795000
Yellow	(3)	3.760000
Yellow	(1)	3.700000
Blue	(1)	3.680000
Red	(2)	3.655000
Red	(1)	3.650000
Green	(1)	3.590000
Red	(3)	3.505000
Blue	(3)	3.270000
Blue	(2)	3.250000
Green	(2)	2.630000
Green	(3)	0.490000

To better illustrate the results indicated in Table 2, Figure 1 was constructed.

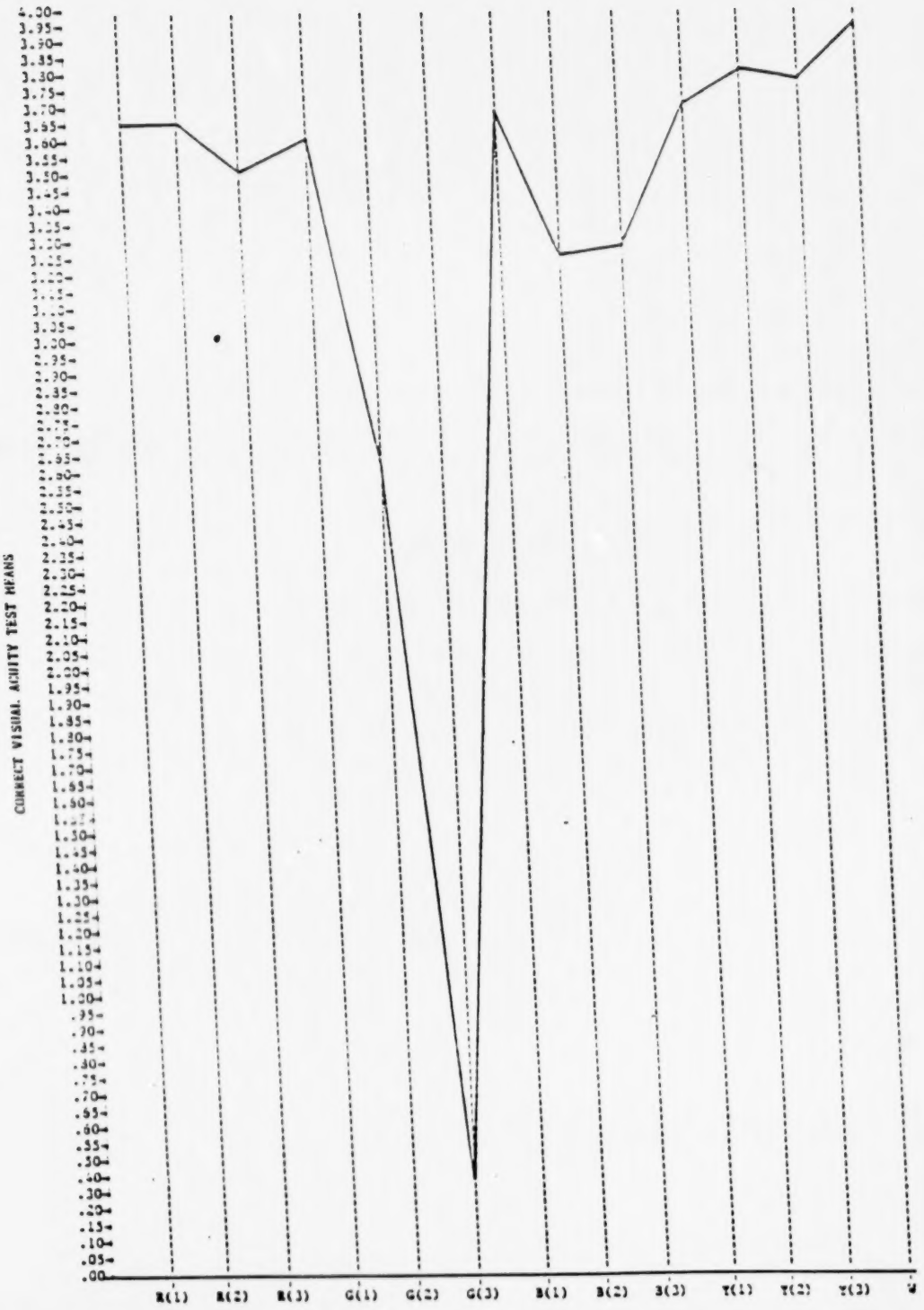


Figure .1 Rank Order of Correct Visual Acuity Test Means, with Time Collapsed Across all Colors.

(Insert figure 1)

As can be seen by examining Table 2 and Figure 1, the color white was seen best followed by yellow level 2 (middle), yellow level 3 (dark), yellow level 1 (light), blue level 1 (light), red level 2 (middle), red level 1 (light), green level 1 (light), red level 3 (dark), blue level 3 (dark), and blue level 2 (middle). The colors providing the poorest mean scores were green level 2 (middle) and green level 3 (dark). The latter provided a rather sharp drop in its visual acuity mean score of 0.490000, a difference of 2.14 from green level 2. The mean difference between white and green level 3 (dark) is 3.4555. Table 3 presents the rank order of correct visual acuity test means, with color collapsed across all times.

TABLE 3. RANK ORDER OF CORRECT VISUAL ACUITY TEST MEANS, WITH COLOR COLLAPSED ACROSS ALL TIMES.

Time	Mean
15 Seconds	3.3180
5 Seconds	3.2900
Unlimited	3.2700
10 Seconds	3.2400

In order to better illustrate the results indicated in Table 3 a graphic respresentation is shown in Figure 2.

(Insert figure 2.)

As can be seen in Table 3 and Figure 2 subjects were better able to see the stimulus (Landolt Rings) at the 15 second presentation time (m = 3.3180), followed by the 5 second time (m = 3.290), when subjects were given as much time as they needed (unlimited) the mean score was 3.270. The poorest stimulus presentation speed was 10 second speed (m = 3.240).

Interaction effects.

In order to show where the interactions of this study's independent variables took place, it was necessary to plot each color across time. These interactions are shown in figure 3.

(Insert figure 3.)

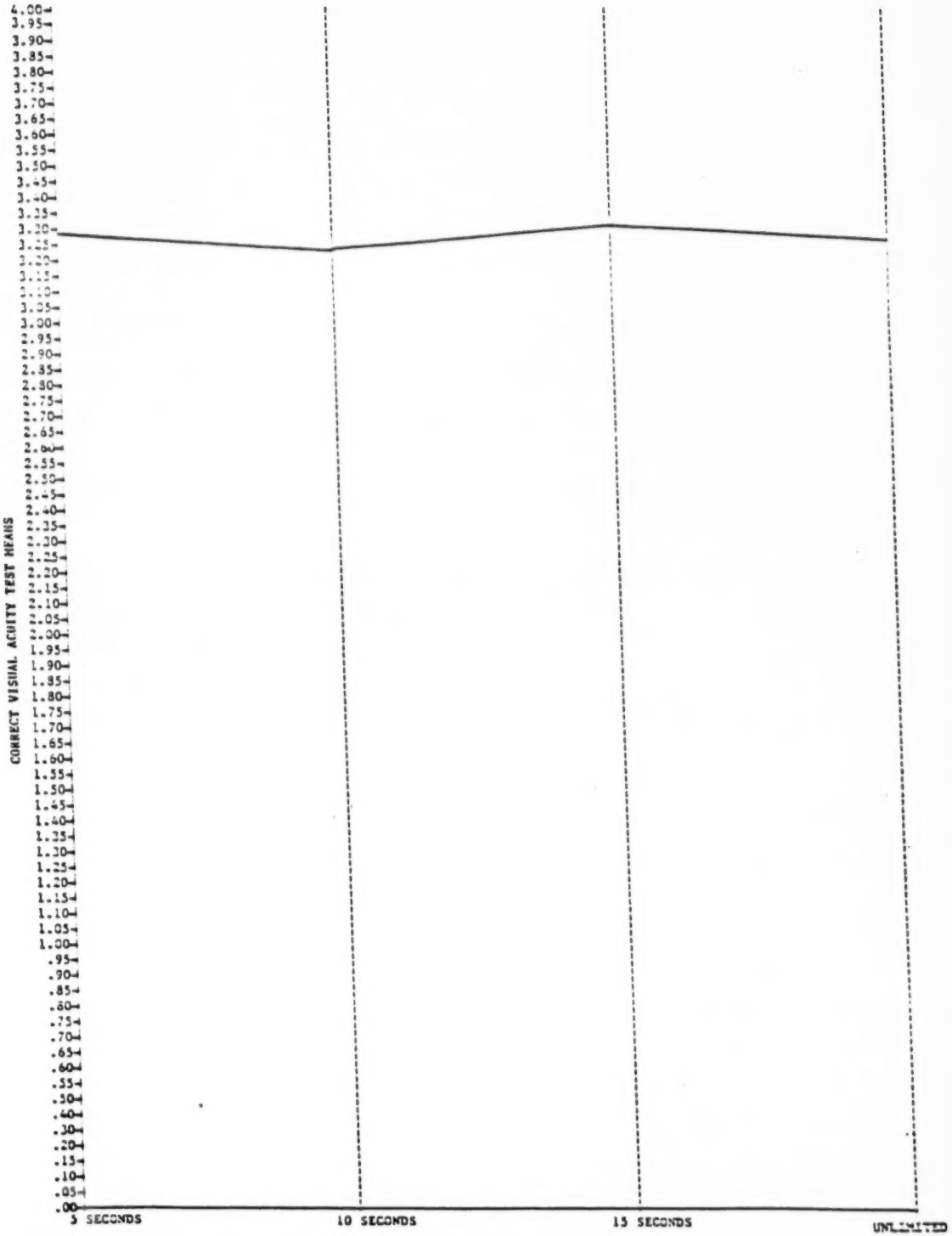
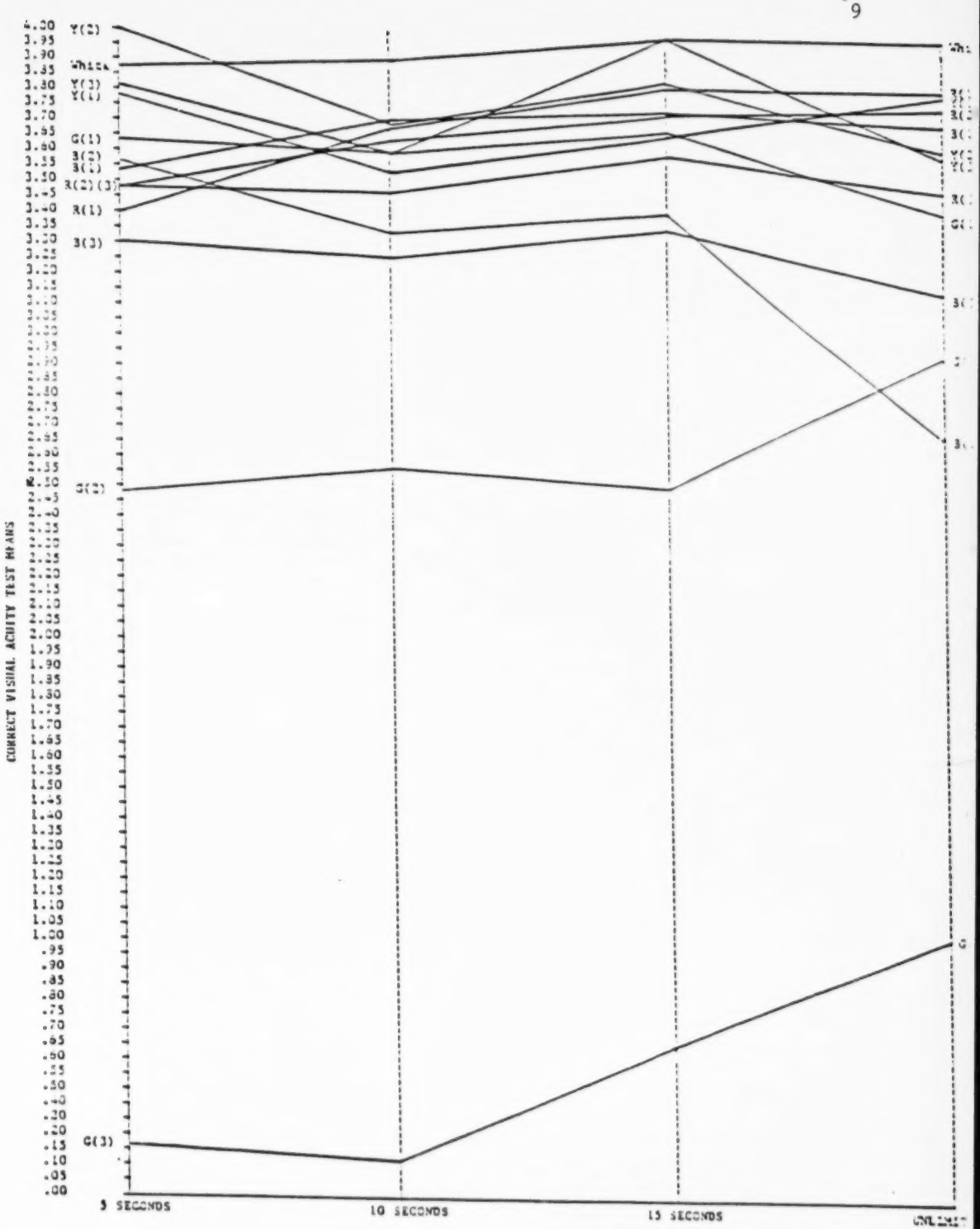


Figure 2. Rank Order of Correct Visual Acuity Test Means, With Color Collapsed Across All Times.



Color and Time Interactions

TABLE 4. HIERARCHIES OF VISUAL ACUITY TEST MEANS BY TIME

5 secs.	10 secs.	15 secs.	unlimited
Yellow (2)	White	White Yel. (3)	White
White	Blue (1)	Yellow (2)	Red (1)
Yellow (3)	Yellow (2)	Red (2) Blue (1)	Yellow (1)
Yellow (1)	Red (1)	Green (1)	Red (2)
Green (1)	Red (2)	Red (1)	Blue (1)
Blue (2)	Yel. (3) Grn. (1)	Yellow (1)	Yellow (2)
Blue (1)	Yellow (1)	Red (3)	Yellow (3)
Red (2 and 3)	Red (3)	Blue (2)	Red (3)
Red (1)	Blue (2)	Blue (3)	Green (1)
Blue (3)	Blue (3)	Green (2)	Blue (3)
Green (2)	Green (2)	Green (3)	Green (2)
Green (3)	Green (3)		Blue (2)
			Green (3)

From the information presented in table 4 and figure 3 the interaction of this study's two independent variables, color and time can be seen and visual acuity tendencies identified. These interactions provide a hierarchy on which specific colors are best at specific times.

After examining where the interactions of this study's independent variables intersect, it can be seen that there are very complex and intricate relationships between the two independent variables. Because of this only those interactions which provided meaningfull differences are discussed.

As can be seen in table 4, subjects were able to see the color white best for three of the four presentation speeds 10 seconds (M = 3.900), 15 seconds (M = 4.00), and unlimited (M = 4.00). At 5 seconds yellow level 2 (medium, M =4.00) was seen best. By far the color providing the poorest visual acuity scores was the color green level 3 (dark) with an overall visual acuity mean at 0.49000 (5 secs = 0.160, 10 secs. = 0.120, 15 secs. = 0.660 and unlimited 1.020). It should be apparent that as overall presentation times increased, so did correct responses. However, there was a drop in correct responses at the 10 second presentation time.

The next poorest color in terms of visual acuity was the color green level 2 (medium), in three of the four presentation times (5 secs. = 2.480, 10 secs. = 2.560, 15 secs. = 2.960). Again, as time increased, so did correct responses. The exception to this was blue level 2 (medium) at unlimited (m = 2.680), giving a disordinal interaction with green level 2.

The next poorest color was blue level 3 (dark) with an overall mean of 3.270 (5 secs. = 3.30, 10 secs. = 3.260, 15 secs. = 3.360, and unlimited = 3.160). It should be noted, however, that when overall mean scores for the various color levels are examined, blue level 3 (dark) did better than blue level 2 (medium). This is do to the disordinal interaction in blue level 2 (medium, m = 2.680) at the unlimited presentation time.

Of those remaining colors, red level 1 (light), red level 2 (medium), red level 3 (dark), green level 1 (light), blue level 1 (light), yellow level 1 (light), and yellow level 3 (dark), there does not appear to be any other meaningful significant interactions.

Summary of findings

From the results presented above it can be concluded that when designing instructional materials the best color to use is the color white, followed by middle yellow, dark yellow, light yellow, light blue, middle red, light green, dark red, dark blue, middle blue, middle green, and dark green. In addition, the longer the amount of time a visual is on screen the more likely it is to be seen. Finally when considering color and time interactions in most instances it can be generalized that as time increases so does a subjects ability to correctly percieve a message regardless of color. It can be further generalized that the best colors to be used in designing projected visuals considering color and time interactions are the colors white, and middle yellow. The poorest colors to use are the colors dark green, middle green, and dark blue.

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